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DENSE PLASMA HEATING AND RADIATION GENERATION.(U)
JAN 79 M KRISTIANSEN, M O HAGLER AFOSR-74-2639
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DENSE PLASMA HEATING AND RADIATION GENERATION

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ANNUAL REPORT NO. 4 ON DENSE PLASMA HEATING AND RADIATION GENERATION.

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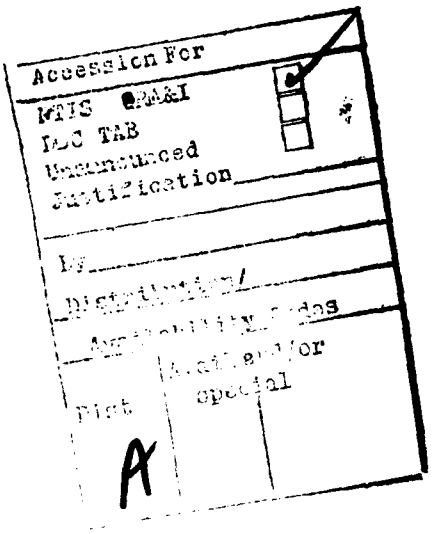
Research objectives

1) Investigations of CO_2 laser heating of dense ($n \sim 10^{23} m^{-3}$), preformed plasma. Experimental results will be compared against predictions by a newly developed computer code.

2) Investigations of nonlinear optical mixing of 9.6 and 10.6 micron laser radiation in a dense plasma.



Status of Research Program

Our ability to carry out research in the general area of CO_2 laser heating of plasmas was greatly enhanced by the transfer several years ago of a large CO_2 laser from the AFWL/DYP. Although the laser was originally designed to be run with two identical, parallel beams, it was apparently never operated in this mode. We therefore made major modifications of the laser to enable one side to run at 10.6 microns and one side at 9.6 microns simultaneously. Some of the modifications involved the redesign of a three-stage Marx bank which can now provide up to 300 kV pulses for the cold-cathode electron gun, increasing the electron gun impedance, and insertion of an absorption cell in the laser cavity. Some modifications (mainly in the electronics) were made to improve the reliability and to reduce the jitter of the CO_2 laser. Spark gap switches, formerly pressurized with SF_6, were modified to use compressed air. This had to be done because any minute leak of SF_6 into the room would result in severe attenuation of the CO_2 laser beam as it propagated from the laser to the plasma source.

A plasma source designed for beat-heating experiments has been made to provide a shorter and more uniform plasma. This is important in obtaining a high power density laser focal spot inside the plasma, which is crucial in beat-heating investigations.

Some preliminary investigations of laser plasma interactions have been made. Burn patterns of the CO_2 laser beam after focussing through the plasma have been recorded. The laser beam was observed to break up into "filaments" (see Fig. 1). Some possible explanations are: self-focussing, non-uniformity of the incident laser beam, plasma inhomogeneity, or the so-called "filamentation instability". Mach-Zehnder interferometry has been employed to measure the perturbation on the plasma density by the CO_2 laser. A typical interferogram is shown in Fig. 2.

Some attempts to observe parallel beam beat-heating have been

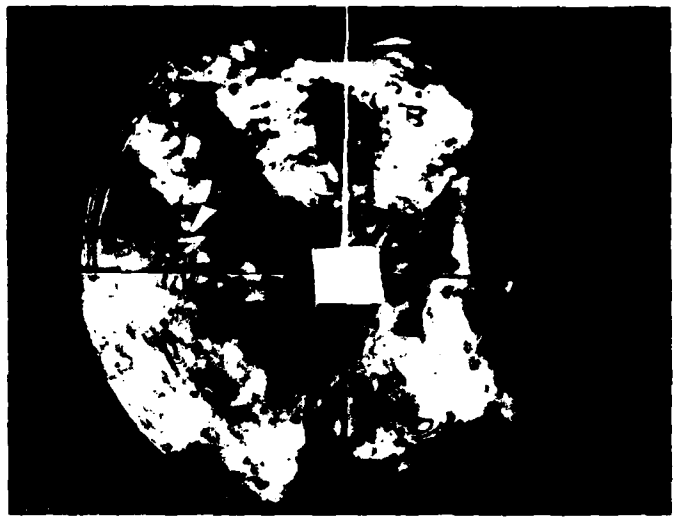


Fig. 1 Burn pattern of CO_2 laser beam after focusing through plasma.

Fig. 2 Mach-Zender Interferogram showing density perturbation by CO_2 laser beam.

made. The diagnostic techniques used were: diamagnetic loop, spectroscopic temperature measurements, and satellite lines associated with the $2^1P - 3^1D$ and $2^1S - 3^1P$ transitions of neutral helium. Results obtained so far have not been too encouraging. This may be partly due to the extremely high laser power density threshold required for parallel beam beat-heating (a factor of 1000 higher than the anti-parallel beam case) and partly due to the sensitivity of the diagnostic techniques used. Currently, we are working on improving the sensitivity of the diagnostic techniques as the beat-heating interaction region is about the same size as the focal spot of the CO_2 laser beam. Observations through a large volume of cold plasma usually result in a very poor signal to noise ratio.

We have come up with a new arrangement for investigating anti-parallel beam beat-heating. A focussing mirror is currently being installed at the exit end of the plasma source to reflect the transmitted laser beam back into the plasma source (see Fig. 3). This arrangement permits superimposing radiations of opposite k-vectors without the very difficult problem of synchronizing the two CO_2 laser beams to nanosecond accuracy.

A continuing effort is being made to upgrade the computer code developed to predict laser-plasma interactions. The mechanisms that have been included in the code to date are:

1) classical inverse bremsstrahlung energy transfer from laser beam to plasma electrons;
2) energy transfer between electrons and ions by equipartition of energy;
3) anisotropic thermal conduction of both electrons and ions;
4) ray tracing of the laser beam to include refraction effects;
5) pressure balance to track the plasma density. Within the last year, the ray tracing has been improved to obtain greater accuracy and also to allow the laser beam to be traced through focuses. In addition, improved modeling of the plasma dynamics is being included at this time (expected completion January 1979).

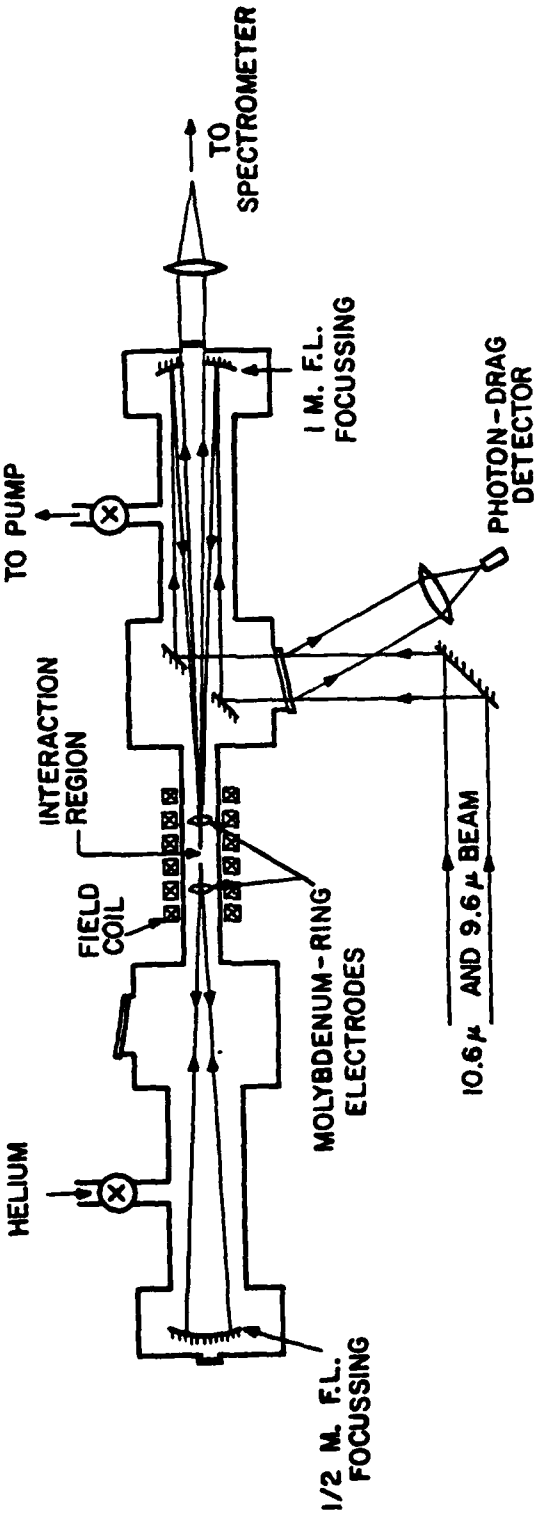


Fig. 3 New Arrangement for anti-parallel beam beat-heating investigation.

An experiment has also been designed to test the validity of the code's predictions. This experiment will utilize the apparatus prepared for the beat-heating experiment to make careful measurements of plasma density and temperature, resolves spatially and temporally. This will be done using spectroscopic methods and Mach-Zehnder interferometry. The results of the experiment and computer code will then be compared. If the agreement is good, this code will be a powerful tool in the theoretical investigation of laser-plasma interactions.

PUBLICATIONS

by Faculty and Staff with

Support from Grant AFOSR-74-2639

Publications.

1. G. M. Molen, M. Kristiansen, M. O. Hagler, and R. D. Bengtson, "CO_2 Laser Heating of a Magnetized Plasma Column," Appl. Phys. Lett. 24 583 (1974).

2. W. C. Nunnally, M. Kristiansen, and M. O. Hagler, "Simple, Multiple Arc,Dielectric Switch Applied to a Theta Pinch," Review of Scientific Instruments 45, 1361 (1974).

3. M. Kristiansen and G. M. Molen, "CO_2 Laser Interaction with Magnetized Plasma," (invited paper, Proc. IEEE Region IV Conf., April 1974.

4. W. C Nunnally, M. Kristiansen, and M. O. Hagler, "Simple, Solid Dielectric, Start Switch," Proc. International Conf. on Energy Storage, Compression, and Switching, Torino, Italy, Nov. 5-7, 1974, Published by Plenum Publishing Corporation.

5. W. C. Nunnally, M. Kristiansen, and M. O. Hagler, "Differential Measurement of Fast Energy Discharge Capacitor Inductance and Resistance," IEEE Trans. on Instrumentation and Measurement, IM-24, 112 (1975).

6. W. C. Nunnally, M. Kristiansen, and M. O. Hagler, "Plasma-Solid Interaction in a Theta Pinch," Appl. Phys. Lett. 26, 496 (1975).

7. D. L. Smith and W. C. Nunnally, "Electromagnetic Leaks Pinpointed and Measured," Laser Focus Magazine, March 1975, p.55.

8. J. E. Thompson, M. Kristiansen, and M. O. Hagler, "Optical Measurements of High Electric and Magnetic Fields," IEEE Trans. on Instrumentation and Measurement IM-25, 1 (1976).

9. M. Kristiansen and M. O. Hagler, "Laser Heating of Magnetized Plasmas," Invited Review Paper, Nuclear Fusion 16, 999 (1976).

10. M. Kristiansen, "Switching Requirements for Fusion Reactors," Proc. DOD Workshop on Pulsed Power, NSWC, White Oakes, Sept. 20-23, 1976.

11. R. E. Dollinger and D. L. Smith, "A Novel High Voltage Probe," Proc. First IEEE Pulsed Power Conf., Lubbock, Texas, Nov. 9-11, 1976.

12. R. E. Dollinger and D. L. Smith, "An Analysis of Co-Axial Pulse Transformers," Proc. First IEEE Pulsed Power Conf., Lubbock, Texas, Nov. 9-11, 1976.

13. R. Druce, M. Kristiansen, and M. O. Hagler, "A Numerical Analysis of High Power Laser Propagation in Magnetized Plasmas," Recent Advances in Plasma Physics, Indian Academy of Sciences, Nov. 29-Dec. 11, 1976.

14. D. L. Smith, M. Kristiansen, and M. O. Hagler, "Ablation Rates of Polystyrene Microspheres in a Theta Pinch Plasma," J. Appl. Physics 46, 11 (1977).

15. E. Y. Chu, R. Druce. L. Gordon, J. Jasper, M. Kristiansen and M. O. Hagler, "An Experimental Arrangement for Laser Beat Heating of Plasmas," Proc. of the Seventh Symposium on Engineering Problems of Fusion Research, Knoxville, Tenn., Oct. 25-28, 1977.

16. G. M. Molen, "Multiple Beam Interferometry," IEEE Transactions on Instrumentation and Measurement, IM 27, 246 (1978).

17. E. Y. Chu, M. Kristiansen, and M. O. Hagler, "Two-Frequency Laser Heating of Dense Plasmas", to be submitted to Plasma Physics.

18. R. Druce, M. Kristiansen, and M. O. Hagler, "Theoretical and Experimental Investigations of Laser-Plasma Interactions", to be submitted to J. Appl. Phys.

PROFESSIONAL PERSONNEL

1. Dr. M. Kristiansen: P. W. Horn Professor, Principal Investigator.
2. Dr. H. O. Hagler: Professor, Co-Principal Investigator.
3. Mr. E. Y. Chu: Research Assistant, Ph.D. Candidate
4. Mr. R. L. Druce: Research Assistant, Ph.D. Candidate
5. Mr. L. B. Gordon: Research Assistant, Ph.D. Candidate

ADVANCED DEGREES CONFERRED

1. December 1974, W. C. Nunnally, PhD: "High Temperature Theta Pinch Plasma Interaction With a Solid Pellet".

2. December 1974, J. E. Thompson, PhD: "Optical Measurements of High Electric and Magnetic Fields.

3. May 1975, D. L. Smith, M.S.E.E.: "Thomson Scattering Diagnostics of the Teepee IA Theta Pinch."

4. December 1975, R. L Druce, M.S.E.E.: "Computer Simulation of Laser-Plasma Interaction in a Magnetic Field."

5. December 1976, J. F. Francis, M.S.E.E.: "High Voltage Pulse Techniques".

6. May 1977, J. S. Jasper, M.S.E.E.: "An Electron Beam Controlled CO_2 Laser".

7. December 1977, D. L. Smith, PhD: "Plasma-Laser Interactions with Solid Polystyrene Microspheres".

8. May 1978, L. B. Gorden, M.S.E.E.: "A High Density Plasma Source".

INTERACTIONS

1) Papers Presented

1. W. C. Nunnally, M. Kristiansen, and M. O. Hagler, "Simple, Solid Dielectric, Start Switch," International Conference on Energy Storage, Compression, and Switching, Torino, Italy, Nov. 5-7, 1974.

2. G. M. Molen and M. Kristiansen, "Carbon Dioxide Laser Interaction with Magnetized Plasma," Australian Institute of Nuclear Science and Engineering Plasma Physics Conf., Sydney, Australia, February 10-11, 1975.

3. M. Kristiansen, "Pulsed Power Technology," Air Force Sigma Xi Chapter, Washington, D.C., April, 1975.

4. W. C. Nunnally, M. Kristiansen, and M. O. Hagler, "Plasma-Solid Laser Interaction in a Theta Pinch," IEEE International Plasma Sciences Conference, Ann Arbor, Michigan, May 14-16, 1975.

5. G. M. Molen, "Multiple Channel Laser Interferometer," IEEE International Plasma Sciences Conference, Ann Arbor, Michigan, May 14-16, 1975.

6. M. Kristiansen, "CO_2 Laser Heating of Magnetized Plasmas," Univ. Stuttgart, FRG, July 24, 1975.

7. M. Kristiansen, series of 3 lectures, entitled:
   "CO_2 Laser Heating of Magnetized Plasmas"
   "Laser and Electron Beam Heating of Plasmas"
   "Plasma Research Studies at Texas Tech University"
   Max Planck Institut für Plasmaphysik, Garching near München, FRG, during period July6 - August 16, 1975.

8. M. Kristiansen, "CO_2 Laser Heating of Magnetized Plasmas," University of Oslo, Oslo, Norway, Sept. 24, 1976.

9. M. Kristiansen, "New Developments in Plasma Heating," Royal Institute of Technology, Stockholm, Sweden Sept. 27, 1976.

10. R. E. Dollinger and D. L. Smith, "A Novel High Voltage Probe," First IEEE Pulsed Power Conf., Lubbock, Texas, Nov. 9-11, 1976.

11. R. E. Dollinger and D. L. Smith, "An Analysis of Co-Axial Pulse Transformers," First IEEE Pulsed Power Conf., Lubbock, Texas, Nov. 9-11, 1976.

12. R. Druce, M. Kristiansen, and M. O. Hagler, "A Numerical Parameter Study of Laser Plasma Interaction," APS Plasma Physics Div. Meeting, San Francisco, California, Nov. 14-20, 1976.

13. M. Kristiansen, Series of 2 lectures on "CO_2 Laser Heating of Magnetized Plasmas," U.S. - India Workshop on Plasma Physics, Ahmedabad, India, Nov. 29 - Dec. 10, 1976.

14. D. L. Smith, M. Kristiansen, and M. O. Hagler, "Ablation Rates of Spherical Polystyrene Pellets in a Theta Pinch," IEEE International Conference on Plasma Science, Troy, New York, May 23-25, 1977.

15. M. Kristiansen, "CO_2 Laser Heating of Magnetized Plasmas," Polish Academy of Sciences, Warsaw, Poland, October 1, 1977.

16. E. Y. Chu, R. Druce, L. Gordon, J. Jasper, M. Kristiansen and M. O. Hagler, "An Experimental Arrangement for Laser Beat Heating of Plasmas," 7th Symposium on Engineering Problems of Fusion Research, Knoxville, Tenn., Oct. 25-28, 1977.

17. R. Druce, M. Kristiansen and M. O. Hagler, "Computor Investigations of Laser-Plasma Interactions", to be submitted to the 1979 IEEE International Conference on Plasma Science, Montreal, Canada.

2) Consulting and Advisory Functions

1. Dr. Kristiansen served as a consultant to Aerospace Corp., El Segundo, Calif. during the period 1974-1976. He worked on pulsed power and plasma physics problems related to the dense plasma focus. Principal contact: Dr. G. M. Molen (now at Old Dominion University).

2. Dr. Kristiansen worked as a consultant to Palisades Institute in 1976-77. He worked on a pulsed power research assessment (DARPA Contract MDA903-76-C-0253). Principal contact: Warren Kramer. The resulting report was classified SECRET.

3. Dr. Kristiansen was a member of the AFWL Pulsed Power Review Panel in 1974-75. The principal AF contacts were Dr's D. Wunsch and A. Guenther.

4. Dr. Kristiansen was a member of the National Academy of Sciences Air Force Study Board on Pulsed Power in 1977 at the AFWL. The final briefing on the study was given by Drs. Beckner (Sandia Labs) and Dr. Kristiansen to Generals Allen, Stafford, and Hendricks at Edwards AFB on Nov. 18, 1977. The final report on the project is forthcoming from the NAS.

5. Dr. Kristiansen was a member of a DOD Study Group which assessed the European State-of-the-art in pulsed power during the Summer of 1978. Principal DOD participants: A. Guenther, AFWL; R. Verga, AFAPL; F. Rose, NSWC. The final report of this study is being completed.

6. Dr. Kristiansen has been intimately involved with the organization

of several DOD sponsored conferences, including: The First IEEE International Pulsed Power Conference, (1976). The Second IEEE International Pulsed Power Conference, (1979), the 13th Modulator Symposium (1978), and the 1976 NSWC Pulsed Power Systems Workshop.

7. Dr. Kristiansen is organizing a pulsed power lecture series for the USAF with support from AFWL, AFOSR, and AFAPL.

8. Dr. Kristiansen has also worked as a consultant on pulsed power and plasma physics problems to LASL from 1974 to the present time.

Unclassified

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

During the past year, the carbon dioxide laser transferred from the AFWL/DYP was modified to run at 10.6 microns and 9.6 microns simultaneously and reliably. A plasma source designed for beat-heating experiments was built and fully diagnosed. Some preliminary investigations of laser plasma interactions were conducted with the plasma source. Beam filamentations were observed when the laser beam was focussed through plasma. Attempts to observe parrallel beam beat-heating were made, although results did not indicate any significant enhanced heatin process. The computer code for analyzing laser-plasma interactions was further

unclassified

20. ABSTRACT

improved. An experiment to test the validity of the code's predictions was also designed. A novel experimental arrangement for anti-parallel beat-heating was designed and is being implemented.